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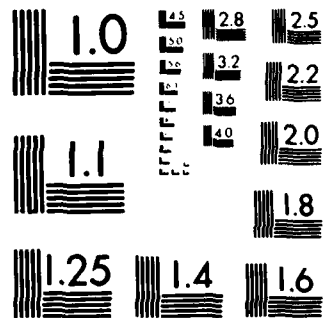   FEB 80   S E HABER, E J LAMAS   N00014-75-C-0729
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APPLICATIONS OF A WAGE-TURNOVER MODEL
TO THE SHIPBUILDING INDUSTRY.

by

Sheldon E. Haber
Enrique J. Lamas

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THE GEORGE WASHINGTON UNIVERSITY
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Abstract
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The object of this paper is to indicate how a model of firm behavior, which incorporates training costs and turnover, can be utilized to answer important decisions relating to hiring and retention. The basic model is adopted from the extant literature and extended in this paper. While the impetus for the paper arises out of research into the shipbuilding labor market, the applications discussed are of general interest to any firm regardless of industry.

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APPLICATIONS OF A WAGE-TURNOVER MODEL
TO THE SHIPBUILDING INDUSTRY*

by

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Enrique J. Lamas

1. Introduction

Economists have given much thought to the relationship between
factor utilization and factor prices. The models developed by the economist,
however, have sometimes neglected considerations that firms must contend
with in determining labor requirements. Only recently with the develop-
ment of the theory of human capital have training costs[1] and turnover
been integrated into models of wage determination[2]. Of the two, train-
ing costs have received the most attention. While it is recognized that
workers leave employers when it is advantageous to do so, few models provide
an explicit link between turnover and the wage rate. As indicated

[1] Included in training costs are all losses in output occurring as a result of
workers participating in the training process. For brevity, we define training
costs to also include the cost of hiring.

[2] See Gary S. Becker, Human Capital: A Theoretical and Empirical Analysis With
Special Reference to Education, Columbia University Press, 1964.

below, training costs and turnover are also central to this paper. The purpose of our study is to indicate how such information can be used for solving some practical problems pertaining to manpower acquisition and retention.

Some relationships between the demand for labor, training, costs, and turnover are fairly obvious. For example, assume two groups of workers are otherwise identical except their turnover rates are different. One would expect the group with the higher turnover to be paid a lower wage even if training costs were the same for both. Thus, the tendency for women to leave the labor force more often than men may explain their lower wage rate.[3] But how much of the observed wage differential can be explained by this factor? This question has been addressed by Goldfarb and Hosek[4] who estimate that only one-quarter of the wage differential between men and women can be explained by differences in turnover.

In this paper we describe the Goldfarb and Hosek model and indicate how it can be applied to the shipbuilding industry where, as is well known, turnover and training costs are high. Their model is then extended by relaxing some of its assumptions. While the impetus for the paper arises out of research into the shipbuilding labor market, the applications discussed are of general interest to any firm regardless of industry.

In Section 1, following Goldfarb and Hosek, it is assumed that two groups of workers who are perfect substitutes for each other have different separation rates but the same marginal value product and training costs. It is further assumed that each group's separation rate is independent of its wage rate. Given these assumptions, which group should a firm hire if it wishes to minimize labor costs? In Section 2, the Goldfarb-Hosek model is extended by dropping the assumptions of equal marginal value product and training costs. In Section 3, the focus is shifted from the hiring problem to the problem of retention. Instead of assuming that the wage rate is

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[3] It should be noted, however, that there is some evidence that men may change employers more often than women.

[4] Robert S. Goldfarb and James R. Hosek, "Explaining Male-Female Wage Differentials for the 'Same Job,'" The Journal of Human Resources, Winter 1976, pp. 98-108.

exogeneously determined, it is assumed that the separation rate is negatively related to the wage rate. The question raised in this part of the paper is the following: How much more can a firm pay a group of workers without raising its labor costs if, as a result of paying a higher wage, the group's separation rate were to decline by a specified amount? The answer to this question is a first step in determining an optimal wage structure.

It must be remarked that the questions raised in this paper are considerably simpler than those faced by employers. Yet they are more complex than those addressed in the extant literature. Also, the data needed to implement the models presented are not available in published form; indeed, not all firms collect the requisite data. If data are collected, they are unlikely to be examined in detail because, heretofore, few models have been formulated to utilize such data. It is hoped that the present study will alleviate this shortcoming.

2. The Basic Model and Applications to the Hiring Decision

The Goldfarb-Hosek model is set within the framework of the profit maximizing firm. It assumes that firms incur training costs for each employee hired and they must recover these costs over the employee's term of employment. The profit maximizing firm recoups its costs by paying employees less than the value of their output, i.e., less than their marginal value product. The difference between marginal value product and the wage rate, discounted to the present and summed over all periods during which the employee remains in the firm's employ is the return to the firm on its investment in training. Since an employee may separate from a firm at any time, employers use an expected value calculation in which the discounted return in any period is multiplied by the probability that the worker will be in the firm's employ during the period.

As Goldfarb and Hosek show, the equilibrium condition for maximizing profits is

$$\sum_{t=0}^{T} \left[\frac{MVP_t - w_t}{(1+r)^t} \right] (1-S)^t - C = 0 \qquad (1)$$

where T is the employer's "labor force time horizon,"[5] MVP_t and w_t are the marginal value product of labor and the wage rate in time period t, respectively,[6] r is the discount rate, S is the employee's separation probability, and C is training costs. The term in brackets is the discounted return during period t; $(1-S)^t$ is the likelihood that the discounted return will be realized during the period. The product of these two terms is the expected present value of the return. The firm maximizes profits by hiring workers until the expected present value of the stream of returns falls into equality with the costs of acquiring an additional worker.

The equilibrium condition noted above can be rewritten in a simpler form, assuming an employee's marginal value product, wage rate, and separation rate are constant through time and that the employer's labor force time horizon is sufficiently long. Under these simplifying assumptions, the steady-state equilibrium condition is given by[7]

$$(MVP - w) \left(\frac{1+r}{r+S} \right) - C = 0 . \qquad (2)$$

Goldfarb and Hosek then use (2) to derive the wage rate differential between two groups of workers which leaves a firm indifferent between hiring one or the other when each group has the same marginal value product and the same training costs. With these additional assumptions, the wage rate differential is found to be[8]

$$w_1 - w_2 = \frac{C}{(1+r)} (S_2 - S_1) . \qquad (3)$$

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[5] The labor force time horizon is the period of time over which a firm makes its calculations of how much to produce and how much of each kind of labor it will employ.

[6] In Goldfarb and Hosek, op.cit., p. 98, equation (1) is stated in real terms. To facilitate the exposition, it has been converted into dollar terms.

[7] See Appendix Note 1.

[8] See Appendix Note 2.

As can be seen from (3), the wage rate differential in favor of the group with the lower separation rate (denoted as group 1) is greater, the larger the difference in the turnover rate between the two groups. In comparing (2) and (3), it is noticed that by assuming both groups of workers have the same marginal value product and the same training costs, the former variable drops out and the latter enters as a parameter (along with the discount rate).

By way of illustrating the economic meaning of (3), consider the case where group 2 workers turn over every period while group 1 workers remain with the firm permanently. In this situation, the firm will be indifferent between paying group 2 workers a wage w_2 and incurring training costs of $\frac{C}{1+r}$ each period and paying group 1 workers a wage $w_2 + \frac{C}{1+r}$. Which of the two groups the firm will hire in order to minimize expenditures on labor will depend on the market wage rate at which each group can be hired. If the firm can obtain as many workers as it wants at the prevailing market wage rate for each group,[9] and if each group's separation rate is independent of its wage rate, labor expenditures will be minimized by hiring group 1 workers provided its wage rate exceeds that of group 2 workers by less than $\frac{C}{1+r}$ dollars. If, on the other hand, group 1's wage exceeds that of group 2 workers by more than $\frac{C}{1+r}$ dollars, it would be more economical to hire the latter. All other things being equal, the wage rate that could be paid to group 1 without its being priced out of the market depends on the costs of training (and the interest rate). The higher the costs of training, the larger the wage differential that can prevail between the two groups.

Equation (3) is of interest from another standpoint since it shows the differential value per worker to the firm in employing two groups with different turnover rates, given training costs and the interest rate. As an example of how this information can be used, consider the problem of determining whether a firm should recruit equally productive workers locally or from more distant places.[10] This problem is particularly acute for large scale firms located in

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[9] That is, each group's supply curve is perfectly elastic.

[10] Recruiting costs are usually included in the calculation of hiring costs. For the purpose of this example, they are treated as a variable cost independent of hiring costs.

small labor markets, as is often the case of shipyards, and is becoming
more prevalent in other industries where establishments are locating in non-
metropolitan areas. The further afield a firm recruits labor, the greater
will be the turnover rate. One reason for this is that the more distant a
worker lives from his place of residence, the greater is the cost of getting
to work. Additionally, workers tend to have stronger ties to the community
in which they live than the one in which they work. Hence, distant workers
who take jobs outside their area of residence are more likely to consider them
as temporary and separate when employment closer to home becomes available.
Where the two groups of workers are available at the same market wage rate,
as would be the case where the wage rate is specified by union contract, and
the supply curve of labor is perfectly elastic for all levels of output con-
templated by the firm, $\frac{C}{1+r} (S_2-S_1)$ represents the cost, or shadow price, of
increased turnover when nonlocal labor is hired; alternatively, it represents
the resources that can be devoted to recruiting labor from the local area,
which would leave labor expenditures, including expenditures on training,
unchanged.[11]

The resources per period to be devoted to recruitment should be such
that the effective wage of local labor, that is, the wage rate plus recruiting
expenditures per period, results in (3) being satisfied. If the wage and
recruiting outlays expended on local labor are less than the amount indicated
by applying (3), profits can be increased by recruiting additional workers
locally. As before, training costs play an important role. All other things
being equal, the higher the cost of training, the greater the advantage of
hiring local workers since hiring workers from distant places entails a greater
risk that training costs will not be recovered.

3. An Extension of the Model and an Additional
   Application to the Hiring Decision

In the preceding section, it was assumed that the marginal value product
of two alternative groups of workers are equal. Additionally, it was assumed

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[11]Since both groups are distinguished only by their place of residence, it
can be assumed that they are perfect substitutes.

that their training costs are the same. In this section, these two restrictions are removed, thereby increasing the class of problems to which the approach underlying the Goldfarb-Hosek model can be applied.

As an example of this larger class of problems, consider the case of a firm faced with the decision of hiring experienced workers or inexperienced workers. All other things being the same, the former would be preferred to the latter because their marginal value product is higher and their cost of training is lower. Additionally, experienced workers are more likely to be older and, hence, have a lower separation rate.[12] But older, experienced workers differ from younger, inexperienced ones in an important way. Because they are experienced, they can command a higher wage rate. Which of the two groups to hire, then, depends on whether the benefits of higher productivity, lower training costs, and lower turnover outweigh the higher wage expenditures required to attract experienced workers.

The Goldfarb-Hosek model can be extended to evaluate the benefits and cost of hiring experienced versus inexperienced workers as follows: As before, we begin by assuming 1) an employee's marginal physical product, wage rate, and separation rate are constant through time, 2) the employer's labor force time horizon is sufficiently long, and 3) an employee's separation rate is independent of his wage rate. In contrast to the earlier model, however, we now assume two groups of workers with different marginal value products and training costs. Under these conditions, the wage differential leaving a firm indifferent between the two groups is[13]

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[12]Because older workers have a shorter work-life expectancy, their rate of return on mobility will be less than for younger workers. A lower rate of return is also likely to prevail with respect to changing jobs. Additionally, older workers will have accumulated more information than younger ones regarding career choice, working conditions in other firms, etc., which reduces the need to change jobs to see if they can improve their employment position.

As noted below, older workers, being more experienced, earn more than younger workers and this may also cause their separation rate to be lower. In this section, only the inverse relationship between turnover and age is considered.

[13]See Appendix Note 3.

$$w_1 - w_2 = (MVP_1 - MVP_2) + C_2 \left(\frac{1+S_2}{1+r}\right) - C_1 \left(\frac{1+S_1}{1+r}\right). \quad (4)$$

From this expression one finds that for $MVP_1 = MVP_2$ and $C_2 = C_1 = C$, the first term on the right equals 0 and the last two terms reduce to $\frac{C}{1+r}(S_2 - S_1)$, that is, (4) reduces to (3) when the assumptions of the previous section are satisfied. Additionally, it is noticed that when $MVP_1 = MVP_2$ and $S_2 = S_1 = S$, the last two terms reduce to $\frac{1+S}{1+r}(C_2 - C_1)$. Thus, all other things being equal, even when two groups of workers have the same separation rate, it will be advantageous to hire the group with the lower training cost. This result differs from the one in the preceding section where no advantage accrues to a firm when both groups have the same separation rate.

The most difficult problem in applying (4) is estimating $MVP_1 - MVP_2$. For some occupations, such as welders, one may be able to obtain a physical measure, for example, feet of weld per day, which can then be converted to a dollar value figure. Another way of getting at this difference is in terms of the differential earnings between older and younger workers doing similar work in other industries. In the absence of information about MVP_1 and MVP_2, the right-hand side of (4) can be estimated by omitting the first term in parenthesis and using the more readily obtainable data on training costs and separation rates; this yields a minimum estimate of the optimal wage differential for the case where $MVP_1 > MVP_2$.

It is readily seen from (4) that more experienced (group 1) workers can be compensated at a higher rate than inexperienced ones because their marginal product is higher, their training cost is lower, and, if they are older, as is typically the case, their separation rate is lower. The hourly wage differential that employers can pay to experienced workers, that is, the wage differential that balances the advantages of hiring

such workers, is shown in the table below for several combinations of the variables in the extended model.[14] In our illustration, with

$$MVP_1 - MVP_2 = \$2,000 \;;^{[15]} \quad S_2 = .03 \;, \quad S_1 = .01 \;;^{[16]} \quad \text{and} \quad \frac{C_2}{1+r} = \$3,000 \;,$$

$\frac{C_1}{1+r} = \$1,000$, experienced workers can be paid as much as $1.43 per hour more than inexperienced ones.[17] The wage differential will vary from industry to industry, depending on the values of the variables in the model. It should be clear, however, that for industries with above average skill requirements, particularly those where value added per worker is high as in shipbuilding, the benefit of hiring experienced workers can be substantial.

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[14] The top block of figures in the table indicates the hourly wage differential when training costs are ignored; in this case, the wage differential is due solely to differences in marginal value product. Columns (1), (3), and (6) indicate the hourly wage differential when the separation rate of each group is the same.

[15] The figure $MVP_1 - MVP_2 = \$2,000$ is somewhat higher than the earnings differential of $1,708 between workers age 35-44 and age 25-34 in durable goods manufacturing in 1970 (see John Martin, The Labor Market of The United States Shipbuilding Industry: 1960-1970, The George Washington University, Institute for Management Science and Engineering, Program in Logistics, Serial T-838, 30 June 1978, unpublished dissertation).

[16] The average monthly quit rate in durable goods manufacturing was .018 in 1978 (see U.S. Department of Labor, Bureau of Labor Statistics, Employment and Earnings Statistics for the United States, Bulletin 1312-11, 1979). No quit rate data are available by experience level, but it is reasonable to assume that the quit rate of inexperienced (experienced) workers is higher (lower) than average.

[17] In 1978, the average hourly wage ratio of production workers in manufacturing was $6.19. See U.S. Department of Labor, op. cit.

Hourly Wage Differentials[a] for Given Differentials

in Marginal Value Product,[b] Training Costs, and

Separation Rate[c]

$MVP_1 - MVP_2$	$S_2 = .01$		$S_2 = .02$			$S_2 = .03$			
	$S_1 = .01$	$S_1 = 0$	$S_1 = .02$	$S_1 = .01$	$S_1 = 0$	$S_1 = .03$	$S_1 = .02$	$S_1 = .01$	$S_1 = 0$
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)

$$\frac{C_2}{1+r} = 0; \qquad \frac{C_1}{1+r} = 0$$

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
0	0	0	0	0	0	0	0	0	0
1,000	.48	.48	.48	.48	.48	.48	.48	.48	.48
2,000	.97	.97	.97	.97	.97	.97	.97	.97	.97
3,000	1.45	1.45	1.45	1.45	1.45	1.45	1.45	1.45	1.45

$$\frac{C_2}{1+r} = 1,000; \frac{C_1}{1+r} = 0$$

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
0	.06	.06	.12	.12	.12	.17	.17	.17	.17
1,000	.54	.54	.60	.60	.60	.66	.66	.66	.66
2,000	1.03	1.03	1.08	1.08	1.08	1.14	1.14	1.14	1.14
3,000	1.51	1.51	1.63	1.63	1.63	1.69	1.69	1.69	1.69

$$\frac{C_2}{1+r} = 3,000; \frac{C_1}{1+r} = 1,000$$

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
0	.12	.17	.23	.29	.35	.35	.41	.47	.52
1,000	.60	.66	.72	.78	.83	.83	.89	.95	1.01
2,000	1.08	1.14	1.20	1.26	1.32	1.32	1.38	1.43	1.49
3,000	1.63	1.69	1.69	1.74	1.80	1.80	1.86	1.92	1.98

$$\frac{C_2}{1+r} = 5,000; \frac{C_1}{1+r} = 2,000$$

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
0	.17	.29	.35	.47	.58	.52	.64	.76	.87
1,000	.66	.78	.83	.95	1.07	1.01	1.12	1.24	1.36
2,000	1.14	1.26	1.32	1.43	1.55	1.49	1.61	1.72	1.84
3,000	1.69	1.74	1.80	1.92	2.03	1.98	2.09	2.21	2.32

[a] Computed by dividing monthly differentials by 172 hours per month (40 hrs/wk x 4.3 wk/mo).
[b] Per year.
[c] Per month.

As before, it is assumed that labor supply schedules are perfectly
elastic. In choosing between experienced and inexperienced workers, firms
compare the wage premium they can pay to the former with the premium they
must pay in the labor market. Labor costs are minimized by hiring ex-
perienced workers when the market wage differential is less than the
differential indicated by (4), and hiring inexperienced ones when it is
larger.[18]

4. Application of the Model to
   the Retention Decision

Up to this point, the context of the discussion has been the hiring
decision where it is assumed that separation rates are independent of wage
rates. We now direct attention to the retention decision. In this context,
it is assumed that separation rates depend on wage rates and that the higher
a group's wage rate the lower will be its separation rate.[19] Additionally,
it is assumed that the firm has discretion over its wage policy, and at
established wage rates arrived at through collective bargaining or informal
negotiations with individual workers, it can obtain as much labor as it
desires.

In establishing a wage structure, a firm will need to give consideration
to the relationship between that structure and turnover. For each group of
workers it will want to balance potential losses in competitive position in
its product market from raising wages to too high a level against potential
losses resulting from excessive induced turnover of its staff if wages are set
too low. The Goldfarb-Hosek model, although not designed to do so, offers

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[18]It is assumed that $MVP_1 - MVP_2$ is constant over the normal range of a
firm's output, otherwise the left-hand side of (4) will vary with the level
of production. This assumption will be met more closely in some contexts
than others.

[19]Empirical evidence indicating that the separation rate is negatively related
to the wage rate is found in a number of studies. See, for example, Vladimir
Stoikov and Robert Raimon, "Determination of Differences in the Quit Rate
Among Industries," American Economic Review, December 1968, pp. 1283-98 and
John Pencavel, "Wages, Specific Training and Labor Turnover in U.S. Manufacturing
Industries," International Economic Review, February 1972, pp. 53-64

insight into some aspects of this problem under the assumption of functional dependence between the separation rate and wage rate.[20]

Consider the case where workers with the same skill work in two different environments, say, indoors and outdoor.[21] Since outdoor work is more arduous, it would not be surprising to find that, all other things being the same, workers assigned to outdoor work have a higher separation rate than those assigned to do indoor work. One way of reducing turnover among outdoor workers is to offer them a premium wage, but how much should be offered? To answer this question one needs to know the functional relationship between S and w, that is, $S = g(w)$, for outdoor workers. Such information is not easily obtained. A much simpler question, which provides a means for searching for the optimal wage, can be phrased as follows: How much more can a firm pay outdoor workers without raising its labor costs, if, as a result of paying a higher wage, the separation rate were to decline by a specified amount? Assuming that in both settings, indoor and outdoor work, $MVP_1 = MVP_2$, $C_1 = C_2 = C$, and, for example, $\frac{C}{1+r} = \$5,000$, we find

from (4) that a premium of 58 cents per hour could be paid outdoor labor without raising costs to achieve a decline in the separation rate from, say, .03 to .01 per month. Of course, it would remain to be seen whether the higher wage rate resulted in the required decline in the separation rate. A firm wishing to be conservative could increase the wage rate in a series of steps. At each step it would determine if the actual decline in the separation rate fell by less than the required amount and would terminate the process when this occurred. In following this sequential procedure a firm would, in effect, be searching for the optimal wage. The benefit to be derived from using the

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[20]It should be noted that in the previous section where the context was the hiring decision, separation rates are assumed to be fixed and firms choose between groups by comparing implicit wage differentials and market wage differentials. As mentioned above, in this section it is assumed firms have discretion in setting wage rates and that they consider their effect on turnover.

[21]In the shipbuilding industry, for example, welders work indoors fabricating parts of the hull and outdoors assembling the hull.

model in this manner is that it provides a criterion for evaluating the impact
of wage changes on turnover. At present, personnel managers can make such
evaluations only on the basis of intuition.

As a second illustration of how the model can be applied to the problem
of retention, consider a firm whose turnover rate of experienced workers has
been increasing over time because the wage paid to this group has not kept
pace with that paid by firms in other industries.[22] Here again, one way to
reduce turnover is to raise wage rates for the affected group. As indicated
by the discussion, it may be possible to do this, thereby improving the structure
of wages without increasing expenditures (including training costs) for labor.
This would be the case if the separation rate of experienced workers fell
more than the required amount indicated by (4) consequent upon a rise in
their wage rate.

The model can also be applied to develop a wage structure to attract
workers who have a relatively high expectation of staying with a firm. Again,
this is an important consideration for firms that engage in a large amount of
on-the-job training. Such a wage structure would pay a lower than competitive
wage initially and a higher than competitive wage later.[23] Workers whose career
planning horizon is short would prefer a higher immediate wage; but those with
a longer career planning horizon would be willing to substitute later wage gains
for a lower initial wage rate and to stay on with a firm until those gains can
be realized. Finding the preferred wage structure in this case requires

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[22] Some evidence that this occurred in firms in the shipbuilding industry
during the late 1960s is found in John Martin, op. cit.

[23] The reverse pattern, that is, less than competitive wages for older workers
and higher than competitive wages for younger workers, appears to prevail in
the shipbuilding industry. See John Martin, ibid. For a further discussion
of the relationship between current and future wage rates over a worker's life
cycle, see Joanne Salop and Steven Salop, "Self Selection and Turnover in the
Labor Market," Quarterly Journal of Economics, November 1976, pp. 619-627.

information about the quit function by age group. As noted, the model provides an empirical basis for experimenting with alternative wage structures without specific information about the quit rate function.[24]

As a last illustration, the model can be utilized to evaluate the consistency of an organization's wage structure among occupations. Used in this manner, (4) implies that occupational wage differences arise from differences in marginal value product, the costs of training, and separation rates. Only the first factor has been extensively treated by economists but, clearly, the other two factors need to be considered. For example, in the military it is assumed that all occupations contribute equally to readiness. But as training costs as well as separation rates differ among occupations, there is a need for adjusting salaries to take account of these factors, and, indeed, the military uses bonus incentives for this purpose. The model discussed in this paper is appropriate for this and similar contexts where it is desirable to develop shadow prices in order to improve on existing wage scales.

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[24] For an optimal solution to the problem of life-cycle wage rates from the perspective of the firm, information is needed on how the turnover rate of young workers varies with future (in addition to current) wages. Since a higher future wage appears to reduce turnover among young people, raising the wage rate of older (experienced) workers and, hence, the wage rate that a young person can obtain when he becomes older, has two effects: It reduces turnover among older (experienced) workers and it also reduces turnover among younger workers (see Richard J. Claycombe, The Supply of Young Craftsmen to an Industry, the George Washington University, Institute for Management Science and Engineering, Program in Logistics, unpublished dissertation (forthcoming)). To the extent that this is so, the likelihood of increasing labor expenditures, when adjusting the wage structure to attract workers with a long planning horizon, is diminished.

5. Concluding Remarks

The objective of this paper has been to indicate how a model of firm behavior that incorporates training costs and turnover information can be utilized to answer important decisions relating to hiring and retention.

A number of applications of the model to the hiring problem are discussed. One application pertains to the issue of whether to hire experienced or inexperienced workers. Although the former can be compensated at a higher wage than the latter because their marginal value product is higher, their training cost is lower and, typically, their separation rate is lower, they also command a higher wage rate in the labor market. The model provides a means of evaluating these diverse kinds of information in determining whether to hire experienced or inexperienced workers.

As is indicated by the discussion, the cost of turnover relative to the wage rate can be high. This finding is consistent with the work of Piore and Doeringer[25] who posit that a major factor in the development of internal labor markets is the priority that firms place on low turnover. This development is fostered by a variety of practices, for example, seniority rules, which invest a worker with quasi-property rights that supplement the wage structure. One reason these practices become established may be the explicit recognition of the impact of turnover on the wage structure, that is, were turnover higher, skill-wage differentials would be larger than they are now and this could be detrimental to worker morale.

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[25] Michael Piore and Peter Doeringer, Internal Labor Markets and Manpower Analysis, D. C. Heath and Company, 1971.

The use of the model in retention decisions is also discussed. Some examples are given relating to the structure of compensation within a firm. One example deals with premium payments to reduce turnover among outdoor workers, assuming they are similar in all respects to indoor workers but their conditions of work are more arduous. Other examples abound where it may be desirable to determine a shadow price in order to improve on existing wage scales. As indicated, the model offers a criterion for determining whether a change in wage rates is cost-effective in terms of its impact on labor expenditures, including expenditures on training.

Although the model yields insights into a number of problems which have heretofore been largely intractable, some caveats are in order. There are substantive aspects that may limit the utility of the model. For example, it is assumed that firms can obtain as much labor as they desire at established wage rates. If a higher wage must be offered to attract new workers, the additional wage payments, which must also be given to currently employed workers, needs to be taken into account. Also, it is assumed that a firm's labor force time horizon is long. Where this is not so, as may be the case in shipbuilding, the model overestimates the shadow price of turnover since training costs must be recouped over a shorter period of time. Other simplifying assumptions imbedded in the model are that marginal value product and the wage rate remain constant over time. [26] Additionally, it is important that the economics of the model be understood before it is applied in any particular context.

Still other limitations pertaining to measurement of the variables in the model should be noted. Besides the problem of measuring marginal value product, there is the nontrivial problem of determining training costs. It is

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[26] The model can be modified to relax these assumptions by assuming that each increases at a constant rate. The model equations for this case are available from the authors upon request.

also not clear as to how the separation rate should be calculated. Normally, only quits would be included in the calculation, but to the extent that workers who are layed off find other jobs, they, too, should be counted since their loss represents unrecouped training expenditures. Despite the difficulties mentioned, it is believed the issues that can be addressed by the model are sufficiently important to warrant the development of approximately accurate data and their analysis along lines indicated in this paper.

Appendix Note 1: <u>The Equilibrium Equation</u>

Proof that $\displaystyle\sum_{t=0}^{T} \left[\frac{(MVP_t - w_t)}{1+r}\right] (1-S)^t - C = 0$ (1)

is approximately equal to

$$(MVP - w) \left(\frac{1+r}{1+S}\right) - C = 0 \qquad (2)$$

when 　　　　　(i) $MVP_t = MVP$ 　　　　　　　$t=0,1,\ldots,T$

　　　　　　(ii) $w_t = w$ 　　　　　　　　　$t=0,1,\ldots,T$

and 　　　　　(iii) $T \to \infty$.

Assuming (i), (ii), and (iii), (1) can be rewritten as

$$\sum_{t=0}^{T=\infty} \left[\frac{(MVP - w)}{(1+r)^t}\right] (1-S)^t - C = 0$$

$$\sum_{t=0}^{T=\infty} (MVP - w) \left(\frac{1-S}{1+r}\right)^t - C = 0$$

$$(MVP - w) \sum_{t=0}^{\infty} \left(\frac{1-S}{1+r}\right)^t - C = 0. \qquad (3)$$

Letting 　　　$\displaystyle\sum_{t=0}^{\infty} \left(\frac{1-S}{1+r}\right)^t = \sum_{t=0}^{\infty} v^t$

where 　　　　$v = \dfrac{1-S}{1+r}$,

then 　　　　$\displaystyle\sum_{t=0}^{\infty} v^t = 1 + v + v^2 + v^3 + \ldots = \frac{1}{1-v} = \frac{1+r}{r+S}$

since $\qquad 0 \leq v \leq 1$ for $0 \leq r \leq 1$ and $0 \leq S \leq 1$.

Substituting $\sum\limits_{t=0}^{\infty} \left(\dfrac{1-S}{1+r}\right)^t = \dfrac{1+r}{r+S}$ in (3) yields

$$(MVP - w) \left(\dfrac{1+r}{r+S}\right) - C = 0 \quad .$$

Appendix Note 2: <u>Wage Rate Differential Equation</u>

Proof that the approximate equilibrium equation

$$(MVP - w) \left(\dfrac{1+r}{1+S}\right) - C = 0 \qquad\qquad (2)$$

implies $\qquad w_1 - w_2 = \dfrac{C}{1+r} (S_2 - S_1) \qquad\qquad (4)$

when $\quad$ (i) $\quad MVP_1 = MVP_2 = MVP$

and $\quad$ (ii) $\quad C_1 = C_2 = C.$

From $\quad$ (2),

$$(MVP_1 - w_1) \left(\dfrac{1+r}{r+S_1}\right) - C_1 = 0$$

$$(MVP_2 - w_2) \left(\dfrac{1+r}{r+S_2}\right) - C_2 = 0 \quad .$$

Assuming (i) and (ii),

$$w_1 = MVP - C \left(\dfrac{r+S_1}{1+r}\right) \qquad\qquad (5)$$

$$w_2 = MVP - C \left(\dfrac{r+S_2}{1+r}\right) . \qquad\qquad (6)$$

Subtracting (6) from (5),

$$w_1 - w_2 = MVP - MVP - C\left(\frac{r+S_1}{1+r} - \frac{r+S_2}{1+r}\right)$$

$$w_1 - w_2 = \frac{-C}{1+r}(S_1 - S_2) = \frac{C}{1+r}(S_2 - S_1).$$

Appendix Note 3:   Extension of the Equilibrium Equation

Proof that the approximate equation

$$(MVP - w)\left(\frac{1+r}{1+S}\right) - C = 0 \tag{2}$$

implies $$w_1 - w_2 = (MVP_1 - MVP_2) + C_2\left(\frac{1+S_2}{1+r}\right) - C_1\left(\frac{1+S_1}{1+r}\right) \tag{7}$$

when (i) $MVP_1 \neq MVP_2$

and (ii) $C_1 \neq C_2$.

From (2)

$$(MVP_1 - w_1)\left(\frac{1+r}{1+S_1}\right) - C_1 = 0$$

$$(MVP_2 - w_2)\left(\frac{1+r}{1+S_2}\right) - C_2 = 0.$$

Assuming (i) and (ii),

$$w_1 = MVP_1\left(\frac{1+r}{1+S_1}\right)\left(\frac{1+S_1}{1+r}\right) - C_1\left(\frac{1+S_1}{1+r}\right) = MVP_1 - C_1\left(\frac{1+S_1}{1+r}\right) \tag{8}$$

$$w_2 = MVP_2\left(\frac{1+r}{1+S_2}\right)\left(\frac{1+S_2}{1+r}\right) - C_1\left(\frac{1+S_2}{1+r}\right) = MVP_2 - C_2\left(\frac{1+S_2}{1+r}\right). \tag{9}$$

Subtracting (9) from (8),

$$w_1 - w_2 = (MVP_1 - MVP_2) + C_2 \left(\frac{1+S_2}{1+r}\right) - C_1 \left(\frac{1+S_1}{1+r}\right).$$

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